TECHNICAL MEMORANDUM

NO. 13

THE LARGE AREA OPERATIONAL APPLICATION OF THE WINTERKILL MODEL USING REALTIME DATA AND EVALUATION OF THE RESULTS

FOR CROP CONDITION ASSESSMENT DIVISION

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREIGN AGRICULTURAL SERVICE

HOUSTON, TEXAS

NOV 13 1980

The Large Area Operational Application of the Winterkill Model Using Real-time Data and Evaluation of the Results	AMENDMENT 1

APPROVED BY:

James R. Hickman, Director, Foreign Crop Condition Assessment Division

1. CHANGES

   To add Mr. Ashburn's name as co-author which was omitted due to an error in the first issue of this Technical Memorandum and to correct the acknowledgement.

2. ACKNOWLEDGMENT

   Mr. Frank Ravet of NASA Earth Resources and Dr. George May for
*-- developing and documenting the model. Additionally, the contribution of Mr. Pat Ashburn, as a lead FCCAD commodity analyst, for performing the large area application test. Their contributions are hereby --
   gratefully acknowledged.

3. PREPARED BY:

Andrew C. Aaronson — 11/2/80

ANDREW C. AARONSON-FAS, IAS, FCCAD — DATE

*-- PAT ASHBURN-FAS, IAS, FCCAD — DATE --

OCT 08, 1981

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APPROVED BY:

James R. Hickman, Crop Condition Assessment Division

1. REASON FOR ISSUANCE

Documents the first large area application of a winterkill model developed by Frank Ravet, NASA/Earth Resources, and George May of the CCAD. Preliminary testing was performed by CCAD. Large area application by CCAD was conducted in conjunction with the operation of the model at the request of EW/CCA AgRISTARS.

2. COVERAGE

This TM evaluates the operational application of the winterkill model, by CCAD, over the USSR winter wheat belt during the 1978/79 crop year.

3. ACKNOWLEDGEMENT

Mr. Frank Ravet of NASA/Earth Resources and Dr. George May for developing and documenting the model. Additionally, the assistance and contributions of Mr. Pat Ashburn, as the lead CCAD commodity analyst, for performing the large area application test and in the preparation of this doucment. Their contributions are hereby gratefully acknowledged.

4. PREPARED BY:

Andrew C Aaronson 11/2/80

ANDREW C. AARONSON-FAS,CP,CCAD DATE

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PART 1.0
INTRODUCTION

1.1 SUMMARY AND CONCLUSIONS

In an effort to improve crop condition analysis capabilities used by the Crop Condition Assessment Division (CCAD), of the Foreign Agricultural Service (FAS) new and/or improved procedures are continuously assessed and tested for the possibility of future integration. A cooperative effort was undertaken in 1978 by the CCAD with the support of NASA, Earth Resources to develop a winterkill indicator model which could be operated in foreign areas. The indicator model would use primary meteorological data elements such as temperature and snow depth and identify geographic areas of potential winterkill. An immediate benefit of the indicator model to the CCAD would be the reduction in the time of analysis of raw weather data performed by CCAD commodity analysts. The model would automatically identify/alarm those areas where winterkill potentials are significant, thus reducing the comprehensive analysis of many primary data elements.

An application test of the winterkill indicator model was planned by the CCAD over the winter wheat belt of the Soviet Union during the 1978-79 crop year using real time data. Success of the model was measured in terms of efficiency, accuracy, objectivity, repeatability, and continuity, with efficiency and accuracy receiving the highest considerations.

The general performance of the winterkill model operated over the test area was favorable. Efficiency gains in meteorological data analyses time were 50-60 percent. Additionally, the model provided a capability to incorporate other influential factors into the model such as wheat hardness and snow cover distribution, thus allowing for the simulation of actual growing conditions.

Model results combined with Landsat data analysis were used to estimate the area loss due to winterkill. The CCAD estimate of 20-25 percent loss of cropland due to winterkill was "in-line" with estimates made by the U.S. Agricultural Attache in the Soviet Union and Soviet newspaper accounts. The CCAD will continue to use the winterkill indicator model in the Soviet Union and further evaluate its performance attempting to assess more fully reliability and continuity of results.

1.2 BACKGROUND

The Crop Condition Assessment Division (CCAD) of the Foreign Agricultural Service (FAS) is responsible for verifying and assessing the impact of adverse conditions on crops in important foreign producing areas and reporting the results to FAS commodity analysts in Washington, D.C. Primary data sources used by CCAD crop analysts for impact assessment include Landsat and meteorological data. Due to the large volume of data analyzed by the CCAD, procedures were

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developed internally and by the research development community which were aimed at reducing this data load to more manageable levels. Models, transforms and other methods which utilize the primary data sources can produce useful indices of crop condition and are an important part of CCAD procedures. For example, the CCAD uses a vegetative index which is computed from the digital Landsat data. The vegetative index measures the relative "greenness" of agricultural areas and is used to direct the analyst where to look for potential stress conditions. Without such an index analysts would be required to perform an in-depth analysis of a significantly larger volume of Landsat data.

In an effort to improve CCAD capabilities new and/or improved procedures are continuously assessed and tested for the possibility of future integration. An effort was undertaken in 1978 by the CCAD and the NASA Earth Resources to develop a winterkill indicator model which could be operated in foreign areas. The indicator model would use primary meteorological data elements such as temperature and snow depth and identify geographic areas where winterkill conditions are likely. In the past CCAD Soviet crop analysts analyzed independently a number of meteorological variables and subjectively assessed the potential for winterkill conditions. An immediate benefit of a winterkill indicator model would be the reduction in the time of analysis of weather data. The indicator model would automatically identify/alarm those areas where winterkill potentials are significant.

Development of the model was completed in 1978 and was tested during the 1978-79 winter wheat crop season in Montana and North Dakota[1]. The Montana and North Dakota test area closely parallels the climatical conditions found in the winter wheat producing areas of the Soviet Union. Parameters for the model were compiled from research materials published in the Soviet Union and the United States.[2,3,4,5] Appendix 1 presents material on the winterkill process and computer program design extracted from a CCAD Technical Memorandum, by Ravet and May, entitled "A Meteorological Model to Aid in the Detection of Winterkill".[1] Results of the pilot test were extremely encouraging. The model successfully alarmed areas where winterkill potentials were significant. These areas were later confirmed by local agriculutural officials in the pilot test areas.

Finalized Large Scale Application Test (LSAT) procedures were not available at the time of the design of the application test of the winterkill model. Therefore, in adherence to a CCAD preliminary draft of LSAT procedures for technology assessment, a test methodology for winterkill indicator model evaluation was undertaken by the CCAD. The application test area was the winter wheat belt of the

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Soviet Union and the time frame was the 1978-79 crop season. Success of the model was to be measured by the CCAD in response to requirements, operational efficiencies and consistency/repeatability of results versus given variances in geographical areas of application.

1.3 PURPOSE

The purpose of the large area test of the winterkill indicator model in the Soviet Union was to evaluate the models accuracy using "live" or real time data, computer integration and operation and general contribution to assessment of crop conditions in the Soviet Union.

1.4 DATA SET

The primary winter wheat belt of the Soviet Union (Figure 1) was selected as the test area for evaluation of the winterkill model. Temperature and snow depth were extracted from World Meteorological Organization (WMO) station data and ETAC grid cell meteorological data, respectively. In total some 125 WMO meteorological stations located in the test area were used to operate the winterkill model. ETAC snow depth data was integrated with the WMO temperature data by geographically associating ETAC grid cells and WMO stations. The two independent data sources were combined and used to operate the winterkill indicator model in the Soviet Union.

Verification data was limited to FAS Agricultural Attache reports, official USSR reports, Soviet newspaper accounts and Landsat data.

1.5 APPROACH

In evaluating a new approach or procedure, objective criteria are used to determine its general performance. Criteria used to evaluate the performance of the winterkill model included standards for the models objectivity, continuity, repeatability, accuracy, and efficiency. Together these criteria measure the overall value or benefit of the winterkill model to the CCAD.

The efficiency criterion was weighed most heavily in evaluating the performance of the winterkill model. The immediate benefit of the model to the CCAD was considered to be the time saved by the commodity analysts in analyzing the large number of primary data elements. The model was used only as an indicator of winterkill, that is, it was not used to objectively estimate the percentage loss to winterkill. The analyst used other data sources such as Landsat digital and imagery data to more fully evaluate the total impact of the winterkill potential. Therefore, accuracy and objective criteria, although important were not ranked as high as the models general efficiency. The model's purpose and value to the CCAD was it's ability to more quickly analyze the primary data inputs and identify those areas of potential winterkill condition. An evaluation of the models continuity and repeatability can only be judged after multiple year and country application tests. The CCAD

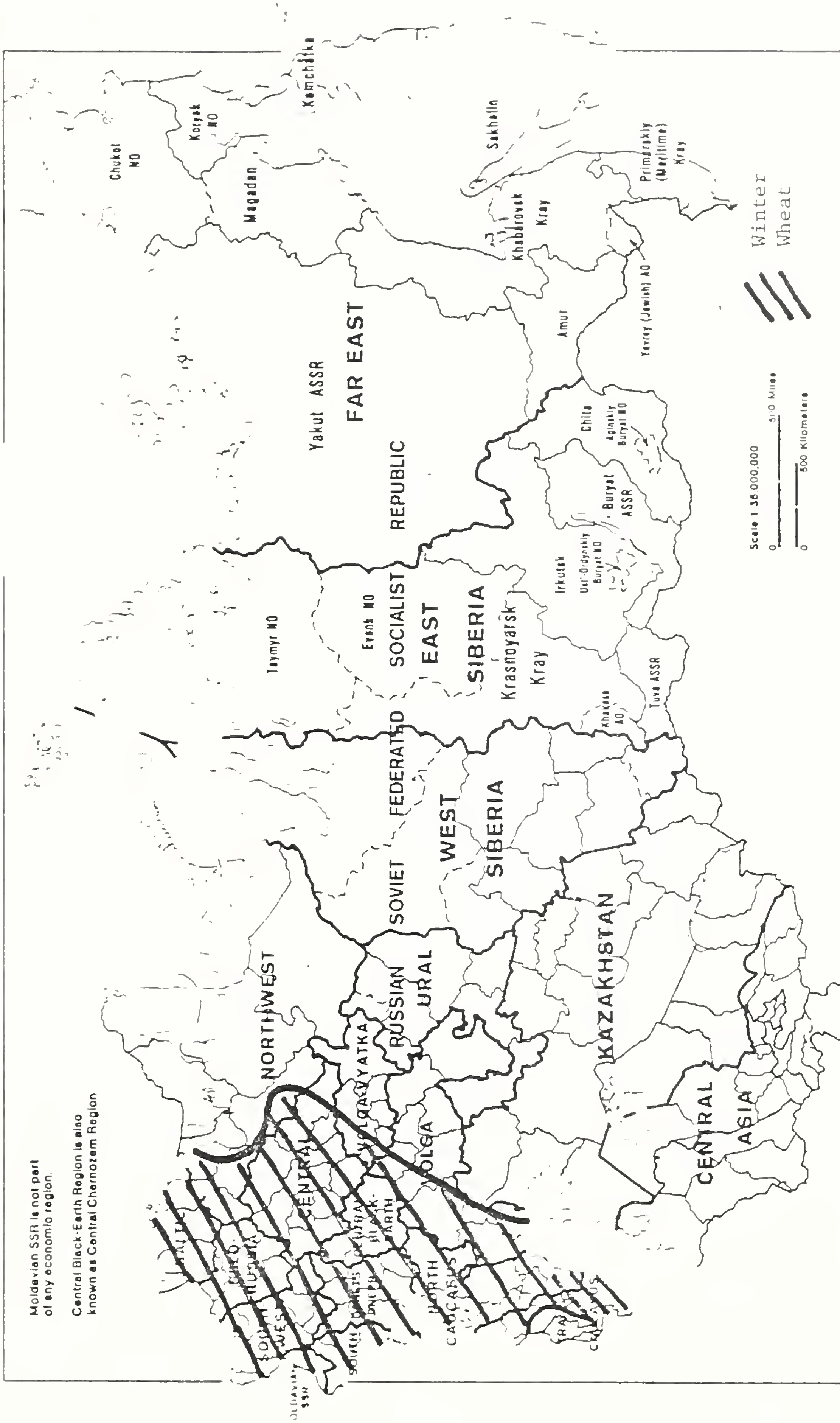

FIGURE 1 - WINTER WHEAT PRODUCING AREA OF THE SOVIET UNION

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will continue to use and evaluate the models performance during the next two to three crop seasons in the Soviet Union to more fully evaluate results continuity and reliability.

PART 2.0
PERFORMANCE EVALUATION

2.1 EFFICIENCY

The general performance of the winterkill model operated over the Soviet Union during the 1978-79 winter crop season was favorable. Efficiency gains in meteorological data analysis time were significant. Comparisons of analyst time expended under the old system of plotting WMO station temperature and ETAC snow depth data and assessing for winterkill potentials versus the time required analyzing the results of the indicator model averaged a savings of 50-60 percent. Under the old system (pre-winterkill indicator model availability) analysts were required to isoline winterkill potentials using the individual WMO station temperature and ETAC snow depth values, a process which consumed 80-85 percent of analysis time. Comparatively, the winterkill indicator model automatically alarmed, and in effect, isolined the winterkill potential regions. The analyst was then free to spend more time on assessing winterkill impact for this specific area using Landsat and other data sources.

An added benefit of the model was its ability to weigh wheat hardness, a characteristic functionally related to temperature and snow depth distribution (refer to Appendix 1). These were two important considerations which could not be objectively evaluated by CCAD commodity analysts using the old system.

2.2 ACCURACY

Evaluating the accuracy of the winterkill indicator model results was difficult due to a lack of confirmed ground observations. Accuracy evaluation was assessed using U.S. Agriculutral Attache reports sent from the Soviet Union, Soviet newspaper accounts and analysis of Landsat imagery. Figure 2 shows a map of the winter wheat producing area of the Soviet Union and the isolines separating regions of different magnitudes of winterkill impact estimated by the CCAD.

As early as June 1, 1979, the CCAD estimated a loss of 25 percent of the total 1978 wheat area due to the impact of both drought and winterkill, with drought estimated to account for 5 percent and winterkill contributing 20 percent to the loss. Two trip reports filed by the U.S. Agricultural Attache in the Soviet Union indicated similar findings. Both geographic areas and intensities were compared and generally were in agreement. Figure 3 shows the relative severity of winterkill indicated by the Agriculture Attache as a result of his two trips during the Spring. Soviet news accounts also provided information about the severity of the winterkill. An article in the Sovetskaya Kray newspaper dated March 30, 1979, reported a 27 percent loss in Stavropol Kray at the same time the CCAD estimated a 25 percent loss in area due to winterkill.

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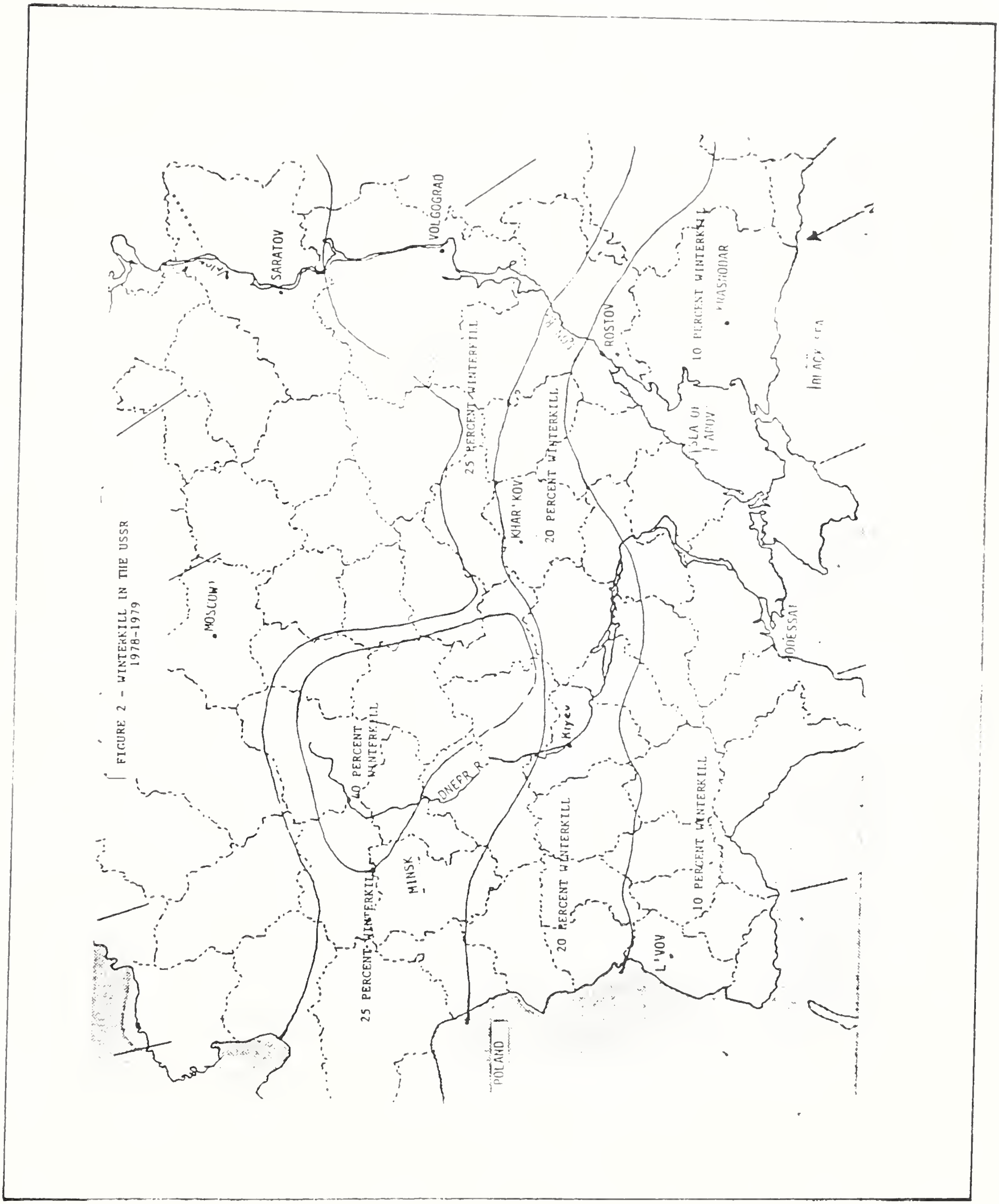

FIGURE 2 - WINTERKILL IN THE USSR 1978-1979

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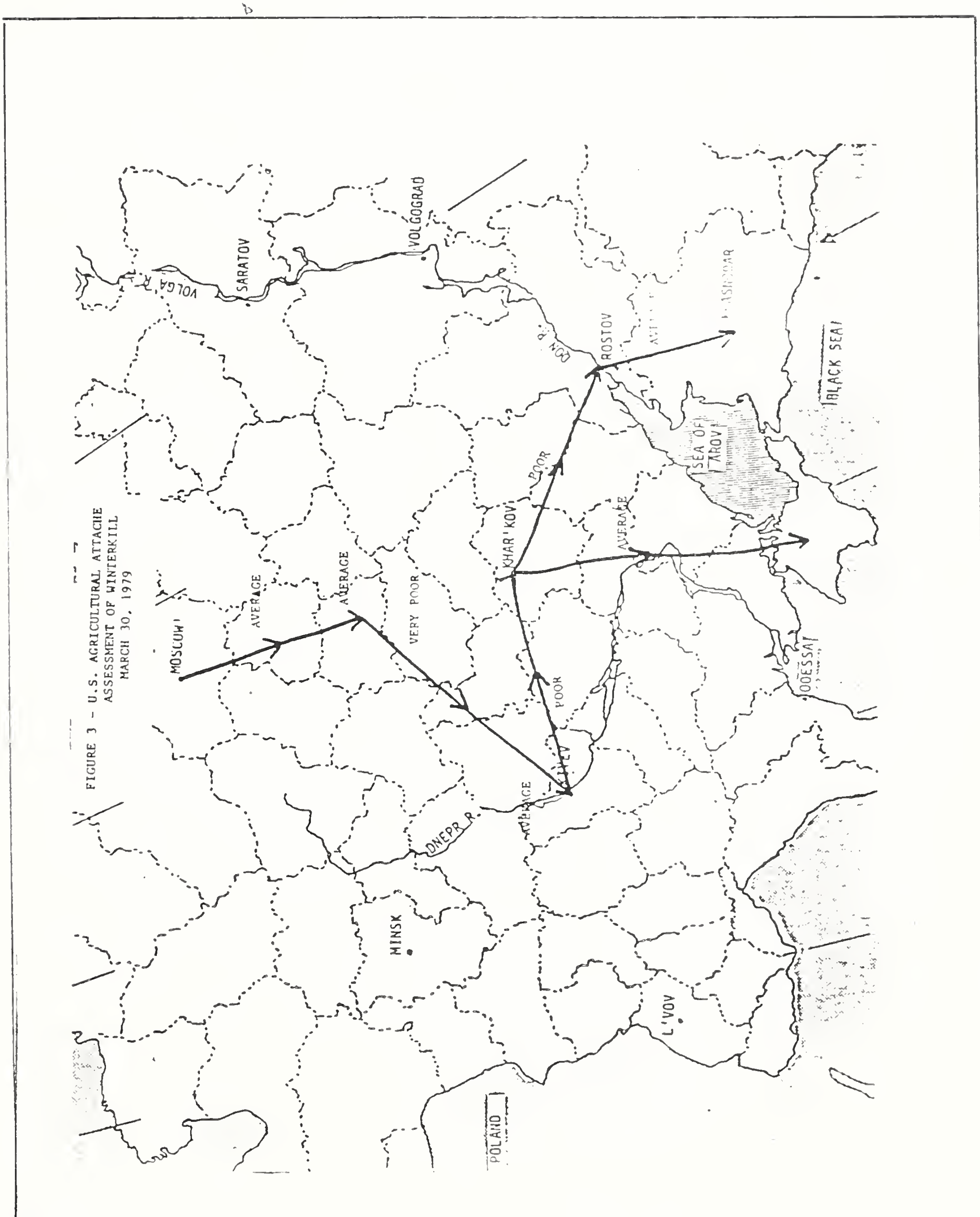

FIGURE 3 - U.S. AGRICULTURAL ATTACHE
ASSESSMENT OF WINTERKILL
MARCH 30, 1979

TABLE 1

CRITICAL TEMPERATURES (C°) OF WINTER WHEAT

UNDER DIFFERENT HARDENING CONDITIONS

		WELL-HARDENED	MODERATELY HARDENED	LESS HARDENED
*	Montana, U.S.A.	-20°	--	-16°
**	Ukraine, Northern Caucasus, White Russia and northwestern oblasts	-19°	-17	-15°

* Taken from Reference 1

** Taken from Reference 2

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TABLE 2

*DIFFERENCE BETWEEN MINIMUM AIR TEMPERATURE AND SOIL TEMPERATURE UNDER VARIOUS SNOW DEPTHS

Snow Cover (CM)	0	3	5	10	15	20	25	30	60
Tem. Difference (°C)	4.0	5.8	6.5	9.0	11.8	13.3	14.1	15.2	17.0

*Taken from Reference 2

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TABLE 3

PERCENT FIELD DISTRIBUTION OF ACTUAL SNOW DEPTH BASED ON REPORTED SNOW COVER DEPTH

REPORTED DEPTH (cm)	ACTUAL DEPTH (cm)								
	0	1-3	4-6	7-10	11-15	16-20	21-30	31-50	51-80
	% FIELD DISTRIBUTION								
1	70	24	5	1	-	-	-	-	-
2	46	33	17	4	-	-	-	-	-
3	27	38	25	9	1	-	-	-	-
4	18	30	36	13	3	-	-	-	-
5	10	25	39	21	5	-	-	-	-
6	7	19	34	29	10	1	-	-	-
7	5	16	30	35	12	2	-	-	-
8	2	11	25	41	15	6	-	-	-
9	2	7	18	42	23	7	1	-	-
10	1	7	14	38	28	9	3	-	-
11	1	4	12	35	31	13	4	-	-
12	1	3	9	29	38	16	4	-	-
13	-	3	7	24	37	19	9	1	-
14	-	2	6	21	35	23	11	2	-
15	-	2	5	17	33	27	14	2	-
16	-	2	4	14	29	29	19	2	-
17	-	1	4	13	25	30	23	3	-
18	-	-	4	10	23	31	26	4	-
19	-	-	2	9	21	30	32	6	-
20	-	-	2	8	19	28	33	6	-
21-30	-	-	1	3	9	21	44	10	1
31-50	-	-	-	-	1	5	25	21	6

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EXHIBIT 1

REFERENCES

1. Ravet, F.W., and G.A. May. "A Meteorological Model to Aid in the Detection of Winterkill", Crop Condition Assessment Division, Foreign Agricultural Service (5-TM, January 24, 1979).

2. Aase, J.K., F.H. Siddoway, and A.L. Black. 1978. Wheat Crown-depth Temperatures Versus Snow Depth. 70th Annual Meeting of the American Society of Agronomy, Chicago, Illinois. December 3-8, 1978.

3. Kulik, M.S. and V.V. Sinekhchikov.. 1966. Lectures on Agricultural Meteorology. Leningrad, Russia. pp. 210-226.

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5. TIME Study Initial Report: Results of OERS Portfolio Development. 1978. General Electric Space Division. NASA Contract #NAS5-23412, MOD 149. pp 4-27 to 4-42.

APPENDIX 1

DESCRIPTION OF WINTERKILL MODEL

Hardening and Temperature Effects

Winterkill is the loss or damage of the plant due to physiological changes resulting from low temperatures and associated physical factors. Some of the primary causes of winterkill are: freezing, heaving, smothering, and physiological drought.

A wheat plant's winter hardiness plays a vital role in minimizing damage and destruction during the cold season. Winter hardiness is dependent on wheat varieties, autumn vegetative growth, and the ability of the plant to harden.

The first phase of hardening is development of frost resistance. This occurs during sunny days with a maximum mean daily air temperature around 12°C and a drop to around 0°C at night (2,3). These conditions are favorable for the concentration of sugars, amino nitrogen, and amide nitrogen in the tissues, which lower the freezing point of the plant.

The second phase of hardening occurs during frost periods and is independent of sunlight. In temperatures ranging from -2 to 5°C the protoplasm undergoes restructuring with the rearrangement of plasma and cell dehydration in the plant (2,4). When plants enter winter dormancy the starches disappear and various types of sugars are accumulated.

The tillering node of a wheat plant is the most vital organ. Death of this node will result in death of the plant. The node will have varying resistance to low temperatures because of the changing weather conditions during the first and second hardening phases. This variation is shown in Table 1 for wheat grown in the Great Plains of U.S.A. and northern areas of Russia.

A plant's winter hardiness does not remain constant throughout the cold season. Low temperature resistance increases at the beginning of winter, in conjunction with the hardening process. At mid-winter the resistance reaches a maximum and then starts declining. Therefore, cold temperatures in late winter or early spring can be extremely harmful to a wheat crop. The duration of low temperatures also plays a role in winterkill. A single day of low temperature may have minor effect on a wheat plant, but if low temperatures persist for three to four days, winterkill will be more severe.

Role of Snow Cover

Snow cover is an important factor in the wintering of wheat. The ability of snow to insulate is approximately 10 times that of mineral soil (2). An accumulation of snow protects a wheat plant and its tillering node from cold air temperatures. A relationship between snow depth and soil/air

temperature has been established and reported in the literature (2). The differences between the air temperature and soil temperature at the tillering node, under various snow depths, are given in Table 2.

It can be seen from Table 2 that as snow depth increases the temperature difference does not increase proportionally. Therefore, an extremely thick snow cover is not necessary to protect a crop from severely cold temperatures.

An uneven snow cover over an area will have differing effects on the winter wheat crop. High winds, uneven terrain, wind breaks and other factors cause variations in snow depth. Russian scientists have gathered data which allow them to predict the percentage of actual depths of snow given a reported snow cover (Table 3). This type of information is needed when developing an indicator model for winterkill.

Structure of Model

The Winterkill Indicator Model was developed on a DEC 11/70 computer using the FORTRAN IV language. The main inputs to the model are daily minimum and maximum temperatures, snow cover, and control data.

The model consists of three parts: control program, meteorological interface program, and winterkill indicator program. The control program is used to regulate the sequence of program calls, and the input/output interface. Inputs to the control program are a meteorological data and error condition.

The meteorological interface program is used to read station data from the meteorological data set for a specific time. It also converts all information to metric, if necessary, and provides some error checking and recovery.

Model Parameters

The winterkill indicator program is the main subprogram. This program calculates the hardness factors, converts station reported snow cover to percent of field cover at various depths, and then calculates the percentage of the wheat nodes that lay in a zone of possible winter damage.

The indicator model contains six hardening stages. The first two occur in the autumn, between mid-October and mid-December. Stages three, four, and five are the winter hardness stages that occur after mid-November. Hardness stage one is reached if for five days the temperature drops below 0°C and rises to approximately 12°C. The days do not have to be consecutive. Stage two occurs if, after reaching stage one, the temperature drops below -5°C for a duration of four days. Hardness stages three, four and five are established as follows: If no autumn hardening occurred, the winter hardness is considered poor and set at stage three in the model; if hardness stage one was reached, but stage two was not, winter hardness stage four (moderate hardening has occured) is set; if all stages one and two are both reached, then winter hardness is good and stage five is set in the model.

In the indicator model the critical temperatures for possible winterkill are based on these hardness stages (Table 4). These temperatures are determined at the tillering mode (3 cm) and the insulating factor of snow and soil (Table 2) is used to adjust the reported minimum air temperatures to soil temperatures at the node. Reported station snow cover is used in a table look-up to determine the areal distribution of the snow (Table 3). Using these factors the model calculates the percentage of tillering nodes that lay in a zone where the temperature dropped to the killing level for each day. Note however, that the possible killing condition must exist for several days for actual winter wheat damage to occur. Therefore, a single day indicator is not important. It must be set for three to four days to become significant.